Design and Fabrication of a small capacity Drone for Agricultural Use

SLTIET

Design and Fabrication of a small capacity Drone for Agricultural Use

A PROJECT REPORT

Submitted by

Vaishnav Hardik (150893119086)

Vaidya Sameep (150893119085)

Rathod Sachin (150893119063)

Bharmal Hatim (150893119010)

Tank Chirag (150893119074)

In partial fulfillment for the award of the degree

Of

BACHELOR OF ENGINEERING

in

MECHANICAL ENGINEERING

Shri Labhubhai Trivedi Institute of Engineering & Technology, Rajkot.

Gujarat Technological University, Ahmedabad.

2017-2018

Shri Labhubhai Trivedi Institute of Engineering & Technology, Rajkot

Mechanical Engineering Department
2017

CERTIFICATE

Date:

This is to certify that the dissertation entitled "**DESIGN AND FEBRICTION OF A SMALL CAPACITY DRONE FOR AGRICULTURAL USE** has been carried out by VAISHNAV HARDIK, VAIDYA SAMEEP, BHARMAL HATIM, RATHOD SACHIN and TANK CHIRAG under my guidance in partial fulfillment of the degree of Bachelor of Engineering in Mechanical Engineering of Gujarat Technological University, Ahmedabad during the academic year 2017-18.

Internal Guide
(Assi. Prof. N.R.Gevaria)

Head of the Department
(Dr. S.B.Rajvir)

Principal
(Dr.B.M.Ramani)

Seal of Institute

ACKNOWLEDGEMENT

We would like to express our sincere thanks to **Dr. Bharat Ramani** (principal of LTIET) for bringing out this project successfully.

We would like to express sincere thanks to **Assi. Prof. N.R.Gevaria** for guiding us in this project successfully.

We wish to express our deep sense of gratitude to **Dr. S.B.Rajvir**, Head of the department of Mechanical engineering for his permission, encouragement, valuable guidance and continuous encouragement accorded to carry this project.

We are also grateful to our all teaching and non-teaching staff members of the department of Mechanical engineering for their help during the course of project work and we are also thankful of the management of Shree Labhubhai Trivedi institute of engineering & technology, Rajkot for their continuous support in our work.

We are thankful to them for their contributions in completing this project work. An assemblage of this nature could never have been attempted without reference to and inspiration from the works of others whose details are mentioned in reference section. We acknowledge our indebtedness to all of them.

We would like to thank our parents and the almighty.

Signature of Student

Vaishnav Hardik (150893119086)

Vaidya Sameep (150893119085)

Rathod Sachin (150893119063)

Bharmal HatimI (150893119010)

Tank Chirag (150893119074)

UNDERTAKING ABOUT ORIGINALITY OF WORK

We here with certify that we tend to be the only authors of this UDP project report which neither any a part of this IDP/UDP project report nor the entire of the IDP/UDP Project report has been submitted for a degree by alternative student(s) to the other University or establishment.

We certify that, to the most effective of our information, the present IDP/UDP Project report does not infringe upon anyone's copyright nor violate any proprietary rights which any ideas, techniques, quotations or the other material from the work of others enclosed in our UDP Project report, printed or otherwise, are absolutely acknowledged in accordance with the quality referencing practices. moreover, to the extent that we have enclosed proprietary material that surpasses the boundary of truthful dealing at intervals the which means of the Indian Copyright (Amendment) Act 2012, we tend to certify that we have obtained a written permission from the copyright owner(s) to incorporate such material(s) within the current IDP/UDP Project report and have enclosed copies of such copyright clearances to our appendix.

Team ID: **3815**

Enrollment No.	Name	Signature
150893119086	Vaishnav Hardik	
150893119085	Vaidya Sameep	
150893119063	Rathod Sachin	
150893119010	Bharmal Hatim	
150893119074	Tank Chirag	

Place: - Rajkot Date:-

Assi. Prof. N.R.Gevaria

(Name of Guide) (Sign. of Guide

ABSTRACT

Agriculture is considered as a back bone of Indian economy with over 70% of the population engaged in agricultural activities in some form or the other. And in current scenario the main problem India is facing is shortage of agricultural labor. So this situation calls for requirement of automation in agriculture Drone. Due to agricultural pesticides exposure around 3 million people located in developing nations like India are at a risk. Pesticides may enter the human body easily through inhalation, ingestion, or by dermal penetration through the skin. Hence the objective of our project is to develop a prototype model of Autonomous AGRICULTURAL-DRONE to facilitate the farmers wherein a click of a button would spray the pesticides

This report describes about a Remote controlled, Battery operated UAV/Drone capable of holding a pesticides spraying mechanism. In this report design of a small capacity drone has been done. Design is basically based on the total weight of the UAV. Also the frame of the UAV is analyzed with respect to various loads and stresses. All the calculations such as thrust force, flight time, section modulus of the arm are also carried out in this report. All motors and batteries are selected on the basis of the calculated values of the various parameters.

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS

CHAPTER 1: LITERATURE REVIEW

1. "Fire Containment Drone" (by William Boyd, Zachary Hood, John Lomi, Chase St. Laurent, Kyle Young)

The goal of this work was to design a UAV system to aid in the control of offshore vessel fires. In order to fulfill above requirement there are certain other requirements which must be accomplished before. The requirements are Mechanical Requirement, Electrical Requirement and Software Requirements. In the designing process of this UAV they have considered Factor of Safety as 1.5. They were also able to achieve the 1.2 meters of spray coverage which quite satisfactory

2. Design and Analysis of a Quad copter Using CATIA (Mathew Thomas, Albin A T, Christin Joseph, Amal Kurian Mathew Jerin Cyriaci)

This research paper present work on the study and analysis of various static and dynamic parameters which affect the UAV performance. There are lot of parameters which are responsible directly or indirectly for the performance of the UAV but this paper is only limited to optimization, determination, design and analysis of the frame parameters. CATIA (Computer Aided Three-Dimensional Interactive Application) enables the creation of 3D parts, from 3D sketches, sheet metal, composites, and molded, forged or tooling parts up to the definition of mechanical assemblies. The length of the arms is taken as 215 mm. The Finite element Analysis of the frame is also carried out with a force of 10N. The maximum stress generated was 2.09MPa. Carbon fiber–reinforced polymer was chosen as the material of the UAV. The dimensions of the center base's diagonal, horizontal and vertical sides were taken 67 mm, 50 mm, and 50 mm respectively.

3. Design of a Quad Copter and Fabrication (by Anudeep M, M.Tech Student, Department of Mechanical Engineering Prasad V Potluri Siddhartha Institute of Technology, Vijayawada)

In this paper, computer aided design of a Quad copter is made and it is also analyzed. The three basic rotations Yaw, Roll and Pitch are also described in this paper in detail. CAD models of top and bottom plate as well as an assembly of fabricated quad copter are generated. The CAD model is prepared and converted to the IGES or STP format to create the FEM model. In this assembly, majority number of parts are made from carbon Fiber while for clamping Aluminum is used. For testing he static strength of the assembly three forces are considered, (1) Thrust Force (2) Centrifugal Force (3) Moment generated by a propeller. Centrifugal force (F_c): $m\omega^2 r$ (Newton), Moment = (F_c × Perpendicular distance b/w prop centre and rod surface) in Newton

4. Design, Analysis and Fabrication of Quadcopter (by Prof. A.V. Javir, Ketan Pawar, Santosh Dhudum, Nitin Patale,Sushant Patil)

In this paper several problems such as Cost, large amount of men power, Human Endangerment, Topographical limitations etc related specially to transportation are discussed. Main objective of this research is to study quad copter flight dynamics and to determine a suitable quad copter RC UAV design. The frame of the quad copter in this paper is made by Aluminum. Three main analysis has been carried out which are (1) Static structural analysis (2) Modal analysis (3) Harmonic analysis. Von misses stress result is minimum 1.9369 Pa and Coming on model are within the limit band, model is safe. Modal analysis is done to find out natural frequencies for 10 different modes. A minimum of 0 Hz and maximum of 637.12 Hz natural frequency is obtained. All the analysis work was done in the ANSYS software. The motors should be selected in such a way that it follows given thrust to weight relationship. Ratio = Thrust / weight =ma / mg = a / g

CHAPTER 2: INTRODUCTION

India is a developing country where still in the 21st century 60 % of the total population highly relies on the Agricultural sector. There are many areas in which still lot of technological development has to be done. In the recent past lot work technological research work has been done the agricultural area to improve the production and quality of the crops.

One of the major areas is pesticides spraying which affects the crop and the farmers the most. Spraying is done by the traditional method in which a heavy box (15 to 20 kg) is carried on the back of the farmers. A pump, battery, tank, piping system and nozzle are the basic components of this system. The whole operation of spraying is carried out manually. The process is very time consuming and it requires lot of men power. But more than that the biggest disadvantage of this system is the weight of the whole system. Due to its weight, the process is very difficult. It causes huge amount of stresses and fatigue on the farmer's body. Also it is very inconvenient and difficult to spray with big weight on the back of the in the muddy soil in the monsoon season.

Many solutions have been suggested till now by the various engineers and researchers. Out of those an Agricultural Drone/UAV may become the fast and accurate solution of this problem. Our main focus is to make a reliable multi copter system which can easily sustain the weight of the pesticides and can spray the pesticides over the certain amount of area. The farmer need not dirty his hands to spray pesticides but instead can sit comfortably in his farm and monitor the entire process with the help of the surveillance system installed in the model.

A Drone is a battery operated device which will carry a pesticide spraying system and can be operated by the remote controller by the farmer. The drone can be with four rotors (Quad copter), six rotors (hex copter), and eight rotors (octa copter). These vehicles use an electronic control system. A drone uses the thrust generated by the rotors to fly and move forward in the air. Rotors are rotated by the DC brushless motors which will be powered by the Lithium Polymer Batteries. The speed and torque of the all motor can be controlled by the Electronic Speed Controller.

The spraying attachment is mounted below the frame of the drone. The spraying system will be comprised of a storage Tank, Pump, Motor and a Battery in a single system. Tubing system will be connected to the spraying attachment. Four nozzles will be provided for the uniform spraying of the pesticides. Whole drone and the drone will be controlled by the operator from the ground.

Whole system will be mounted on the frame of the drone. Frame is comprised of a top plate, bottom plate and a mounting plate. The frame will have a total six arms. The arms will be of hollow rectangular cross section. Aluminum alloy (A 5059) will be the material for both arms and plates. Some other materials can be used like carbon fiber, polycarbonate, balsa wood, G10 etcetera. All the materials that can be used as frame materials are compared.

2.1 Spraying Methods:

One of the more common forms of pesticide application, especially in conventional agriculture, is the use of mechanical sprayers.

1) Backpack Sprayer:

One type of backpack sprayer is a compressed air sprayer with a harness that allows it to be carried on the operator's back.

Another type of backpack sprayer has a hand-operated hydraulic pump that forces liquid pesticide through a hose and one or more nozzles. The pump is usually activated by moving a lever. A mechanical agitator plate may be attached to the pump plunger. Some of these sprayers can generate pressures of 100 pounds per square inch (psi) or more. Capacity of both these types of backpack sprayers is usually 5 gallons or less.

Fig. 1: Backpack Sprayer

Hydraulic sprayers consist of a tank, a pump, a lance (for single nozzles) or boom, and a nozzle (or multiple nozzles). Sprayers convert a pesticide formulation, often containing a mixture of water (or another liquid chemical carrier, such as fertilizer) and chemical, into droplets, which can be large rain-type drops or tiny almost-invisible particles. This conversion is accomplished by forcing the spray mixture through a spray nozzle under pressure. The size of droplets can be altered through the use of different nozzle sizes, or by altering the pressure under which it is forced, or a combination of both.

Large droplets have the advantage of being less susceptible to spray drift, but require more water per unit of land covered. Due to static electricity, small droplets are able to maximize contact with a target organism, but very still wind conditions are required. But, in this type of spraying, the labor has to carry all the weight of the pesticides filled tank which causes fatigue to labor and hence reduces the human capacity.

2) Lite –Trac

Lite-Trac is a trading name of Holme Farm Supplies Ltd, a manufacturer of agricultural machinery registered in England and based in Peterborough. The Lite-Trac name comes from "lite tractor", due to the patented chassis design enabling the inherently very heavy machines manufactured by the company to have a light footprint for minimum soil compaction.

Fig. 2: Lite-Trac

Holme Farm Supplies Ltd agricultural products, sold under the Lite-Trac name, include tool carriers, self-propelled lime and fertilizer spreaders, sprayers, granular applicators and tank masters. Lite-Trac is currently the manufacturer of Europe's largest four-wheeled self-propelled crop sprayers. The company's products are identifiable by the combination of unpainted stainless steel tanks and booms with bright yellow cabs and detailing. A Lite-Trac crop sprayer, or liquid fertilizer applicator, mounts onto the SS2400 Tool Carrier centrally between both axles to maintain equal weight distribution on all four wheels and a low centre of gravity whether empty or full. The stainless steel tanks are manufactured in capacities of up to 8,000 liters, whilst Pommieraluminium booms of up to 48 meters can be fitted, making these Europe's largest four-wheeled self-propelled sprayers.

3) Motorcycle Driven Multi-Purpose Farming Device (Bullet Santi)

In 1994, Mansukhbhai Jagani developed an attachment for a motorbike to get a multi-purpose tool bar. It which addresses the twin problems of farmers in Saurashtra namely paucity of laborers and shortage of bullocks. This motor cycle driven plough (Bullet Santi) can be used to carry out various farming operations like furrow opening, sowing, inter-culturing and spraying operations. Mansukhbhai's intermediate-technology contraption proved efficient and cost-effective for small-sized farms.

Fig. 3: Bullet Santi

It could plough one acre (0.4 ha) of land in less than half an hour on just two liters of diesel oil. Using motorbike-santi, the cost of weeding a typical field was found to be just Rs 8/ha because as much as 10 ha land could be covered in a single day. But, this spraying equipment needs fuel for its running and proper operation which increases its operating cost.

4) Aerial Sprayer

Aerial sprayer is another type of spraying; it is beneficial for the farmers having large farms. This technique is not affordable by farmers having small and medium farm. It is modern technique in agricultural field. In aerial spraying the spraying is done with the help of small helicopter controlled by remote. On that sprayer is attached having multiple nozzles and sprayed it on the farm from some altitude. It is less time consuming and less human effort required spraying fertilizers.

Fig. 4: Aerial Sprayer

2.2 What is Drone/UAV? What are the advantages of a Drone/UAV?

Drone stands for Dynamic Remotely Operated Navigation Equipment. A Drone, also called unmanned aerial vehicles (UAVs), is a multi rotor helicopter that is lifted and propelled by number of rotors.

Control of vehicle motion is achieved by altering the rotation rate of one or more rotor discs, thereby changing its torque load and thrust/lift characteristics by using a microcontroller.

It has no human pilot onboard, and instead is either controlled by a person on the ground or autonomously via a computer program.

Fig. 5: UAV/ Drone

Fig. 6: UAV/ Drone

These UAVs copters are having so many applications due to following advantages

1. No gearing required between the motor and the rotor
2. No variable propeller pitch is required for alternating multi rotor
3. Minimum mechanical complexity
4. Low maintenance
5. Less loads on the center plates
6. Payload augmentation

2.3 Terminology of UAV/Drone

<u>Types</u>

ARF: “Almost Ready to Fly“: a UAV which comes assembled with almost all parts necessary to fly. Components like the controller and receiver may not be incl

BNF: “Bind and Fly“; the UAV comes fully assembled and includes a receiver. You only need to choose a compatible transmitter and “bind” it to the receiver.

DIY: “Do It Yourself“, which is now commonly used to mean “custom”. This normally involves using parts from a variety of different suppliers and creating or modifying parts.

Multi rotor: “Multi rotor” simply means an aircraft with multiple rotors

Size (mm): "Size" is normally provided in millimeters (ex 450mm) and represents the greatest point to point distance between two motors on a UAV. Size can also determine the "class" of UAV (micro, mini etc).

Spyder: A "Spyder" type UAV (normally quad or hex) is one where the supporting arms are not symmetric in both axes when looked at from the top.

Mechanics

CG "Center of Gravity": This is the point on the aircraft where there is equal weight distributed on all sides.

Clamp: A "Tube clamp" is a device normally used on a round tube in order to connect it to another device (such as a motor mount or a UAV's body).
Connectors: In order to plug and unplug wires, connectors are used at the ends of wires. Common connectors for batteries are Deans & XT60, while connectors for the flight controller and sensors are 0.1″spaced.

Dampeners: These are molded rubber parts used to minimize vibration transmitted throughout a UAV Frame. The frame is like the "Skeleton" of the aircraft and holds all of the parts together. Simple frames have motors connected to aluminum or other lightweight extrusions ("arm") which then connect to a central body.

Landing Gear: Multi rotor landing gear normally does not have wheels as you might find on an airplane. This is to prevent it from moving when on the ground and reduce overall weight

Prop Guards: "Propeller guards" are material which cur round a propeller to prevent the propeller from contacting other objects. They are implemented as a safety feature and a way to minimize damage to the UAV

BEC: "Battery Eliminator Circuit": a voltage regulator built into the ESC which can provide regulated 5V DC power to any electronics which need it.

Blades: Propeller blades are the aerodynamic surface which generates lift. A propeller normally has two to four blades which can be fixed or folding.

CW / CCW: CW indicates clockwise rotation and CCW indicates Counter-Clockwise rotation. On a multi rotor aircraft, you would normally use pairs of counter-rotating propellers. 5rotor aircraft, you would normally use pairs of counter-rotating propellers.

ESC: "Electronic Speed Controller" is the device which connects to the battery, motor and flight controller and controls the speed at which the motor rotates

Li-Po: "Lithium Polymer" is the most common battery used in drones and UAVs because of its light weight (versus storage capacity) and high current discharge rates. There are other types of Lithium-based batteries available on the market as well (Li-Fe, Li-Mn, Li-On etc).

Motor: The motor is what is used to rotate the propellers; in small UAVs, a brushed motor is most often used, whereas for larger UAVs, a "Brushless" motor is much more common

PCB: A "Printed Circuit Board" is the flat fiberglass part with many components soldered to it. Many electronic products have a PCB.

Power Distribution: In order to power so many different devices used in a UAV, the battery must be split, which is where the Power Distribution (board or cable) comes into play. It takes the single positive and negative terminals of the battery and provides many different terminals / connection points to which other devices (operating at the same voltage) can receive power.

Propellers: The propellers are what provides the thrust and are more similar to those used in airplanes rather than on helicopters.

Prop Adapter: A device used to connect the propeller to the motor.

Prop Saver: A type of hub which mounts on top of your motor and replaces the prop adapter. In the event of a crash, a part of the prop saver is lost in an attempt to save the propeller.

Servo: A servo is a type of actuator which, provided the right signal, can move to a specific angular position

Thrust: The "thrust" is the force which a specific motor and propeller can provide (at a certain voltage). Usually measured in kilograms (Kg) or pounds (Lbs)

Control

Base / Ground Control Station: Instead of (or in addition to) a hand held transmitter, a station (normally in a case or mounted to a tripod) is used to house / integrate the necessary components used to control a UAV. This can include the transmitter, antenna(e), video receiver, monitor, battery, computer and other devices.

Binding: The term "binding" refers to configuring a handheld transmitter so it can communicate with an receiver; if a transmitter came with a receiver, it should have been done at the factory.

Channel: The number of channels on a transmitter relates to the number of separate signals it can send.

Flight Controller: The "Flight Controller" is what would be considered the "brain" of a UAV and handles all of the data processing, calculations and signals. The core of a flight controller is often a programmable "microcontroller". The flight controller mayhave multiple sensors onboard, including an accelerometer, gyroscope, barometer, compass, GPS etc. If the flight controller has the ability to control the aircraft on its own (for example to navigate to specific GPS coordinates), it may be considered to be an "autopilot".

Transmitter / Radio: The "transmitter" is what generates the control signal(s) wirelessly to the receiver.

Pitch: Pitch is the angle of the nose to tail with respect to the ground, or in other words, the rotation of an aircraft about the axis from wing to wing Pitot Tube A device which measures air speed.

Roll: Roll is the rotation of the aircraft along the axis from its nose to its tail.

Yaw: Yaw is the rotation of an aircraft about an axis perpendicular (90 degrees to) to the plane formed between the nose / tail and wing tips.

2.4 Different Configurations of a UAV/Done

1. **Tricopter**

- **Description:** A UAV which has three arms, each connected to one motor. The front of the UAV tends to be between two of the arms (Y3). The angle between the arms can vary, but tends to be 120 degrees. In order to move, the rear motor normally needs to be able to rotate (using a normal RC servo motor) in order to counteract the gyroscopic effect of an uneven number of rotors, as well as to change the yaw angle. A Y4 is slightly different in that it uses two motors mounted on the rear arm, which takes care of any gyroscopic effects – no servo is therefore needed.

Fig. 7: Tricopter

- **Advantages:** Different "look" for a UAV. Flies more like an airplane in forward motion. Price is theoretically lowest among those described here since it uses the fewest number of brushless motor (and ESC)

.

- **Disadvantages:** Since the copter is not symmetric, the design uses a normal RC servo to rotate the rear motor and as such, the design is less straightforward than many other multi-rotors. The rear arm is more complex since a servo needs to be mounted along the axis. Most, though not all flight controllers support this configuration.

2. **Quad copter**

- **Description:** A "quad copter" drone which has four arms, each connected to one motor. The front of the UAV tends to be between two arms (x configuration), but can also be along an arm (+ configuration).
- **Advantages**: Most popular multi-rotor design, simplest construction and quite versatile. In the standard configuration, the arms / motors are symmetric about two axes. All flight controllers on the market can work with this multi rotor design.
- **Disadvantages:** There is no redundancy, so if there is a failure anywhere in the system, especially a motor or propeller, the craft is likely going to crash.

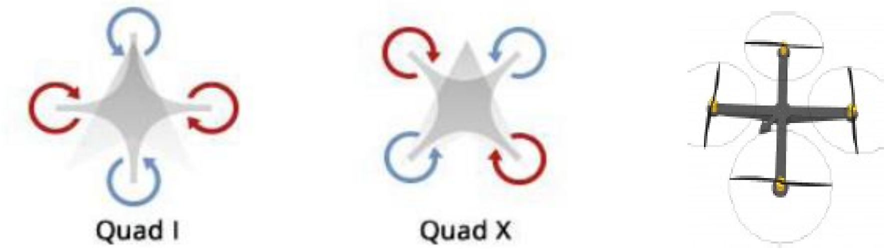

Fig. 8: Quad copter

3. **Hex copter**

- **Description:** A "hex copter" has six arms, each connected to one motor. The front of the UAV tends to be between two arms, but can also be along one arm.
- **Advantages:** It is easy to add two additional arms and motors to a quadcopter design; this increases the total thrust available, meaning the copter can lift more payload. Also, should a motor fail, there is still a chance the copter can land rather than crash. Hexacopters often use the same motor and support arm, making the system "modular". Almost all flight controllers support this configuration.
- **Disadvantages:** This design uses additional parts, so compared to a quadcopter which uses a minimum number of parts, the equivalent hexacopter using the same motors and propellers would be more expensive and larger. These additional motors and parts add weight to the copter, so in order to get the same flight time as a quadcopter, the battery needs to be larger (higher capacity) as well.

Fig. 9: Hex copter

4. **Y6 Hex copter**

- **Description:** A Y6 design is a type of hex copter but rather than six arms, it has three support arms, with a motor connected to either side of the arm (for a total of six motors). Note that the propellers mounted to the underside still project the thrust downward.

Fig. 10: Y6 Hex copter

- **Advantages:** A Y6 design actually eliminates a support arm (as compared to a quadcopter), for a total of three. This means the copter can lift more payload as compared to a quadcopter, with fewer components than a normal hex copter. A Y6 does not have the same issue as a Y3 as it eliminates the gyro effect using counter-rotating propellers. Also, should a motor fail, there is still a chance the copter can land rather than crash.

- **Disadvantages:** This uses additional parts, so compared to a quad copter which uses the same components; the equivalent hex copter would be more expensive. Additional motors and parts add weight to the copter, so in order to get the same flight time as a quad copter, the battery needs to be larger (higher capacity) as well. The thrust obtained in a Y6 as opposed to normal hex copter is slightly lower (based on experience), likely because the thrust from the top propeller is affected by the lower propeller. Not all flight controllers support this configuration.

5. **Octocopter**

- **Description**: An octocopter has eight arms, each connected to one motor. The front of the UAV tends to be between two arms.
- **Advantages:** More motors = more thrust, as well as increased redundancy.
- **Disadvantages:** More motors = higher price and larger battery pack. When you reach this level. most users are looking at very heavy payloads such as DSLR cameras and heavy gimbal systems. Given the price of these systems, added redundancy is really important.

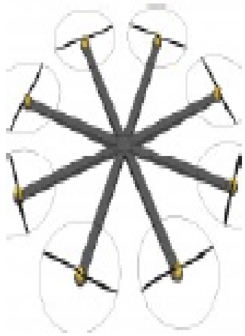

Fig. 11: Octocopter

6. **X8 Octocopter**

- **Description:** An X8 design is still an octocopter, but has four support arms, each with a motor connected to either side of each arm, for a total of 8 motors.
- **Advantages**: More motors = more thrust, as well as increased redundancy. Rather than using fewer yet more powerful motors, octocopters provide added redundancy in the event of a motor failure.
- **Disadvantages:** More motors = higher price and larger battery pack. When you reach this level. most users are looking at very heavy payloads such as DSLR cameras and heavy gimbal systems.

Fig. 12: X8 Octocopter

2.1 **Flight control**

A Hex copter consists of six motors evenly distributed along the hex copter frame as can be seen in figure 13. The circular arrow represents the spinning rotors of the hexacopter and the arrows represent the rotation direction. Motors one, three and five rotate in a clockwise direction using pusher rotors. Motor two, four and six rotate in a counter-clockwise direction using puller rotors. Each

Fig. 13: hexacopter

motor produces a thrust and torque about the center of the hexacopter. Due to the opposite spinning directions of the motors, the net torque about the center of the hexacopter is ideally zero, producing zero angular acceleration. This eliminates the need for yaw stabilization.

1. **Roll:** Roll is provided by increasing (or decreasing) the speed of the left rotor speed and right motors. This causes the quadcopter to turn along the y axis. The overall vertical thrust is the same as hovering due to the front and back motors; hence only roll angle acceleration is changed. Figure 14 shows an example of roll movement of a quadcopter. As the right motor slows down, the forces created by the corresponding rotor are less then the forces created by the left rotor. These forces are represented by the blue arrows. This causes the quadcopter to tip to the right and this movement is represented by the red arrow

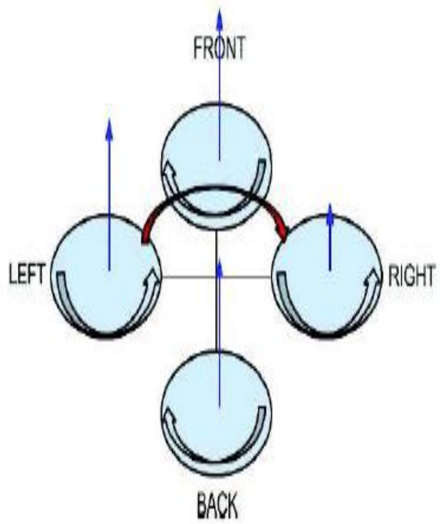

Fig. 14: Roll movement

2. **Pitch :** Pitch is provided by increasing (or decreasing) the speed of the front or rear motors. This causes the quadcopter to turn along the x axis. The overall vertical thrust is the same as hovering due to the left and right motors; hence only pitch angle acceleration is changed. Figure 15 shows an example of pitch movement of a quadcopter. As the front motor slows down, the forces created by the corresponding rotor are less then the forces created by the back rotor. These forces are represented by the blue arrows. These forces cause the quadcopter to tip forward and this movement is represented by the red arrow.

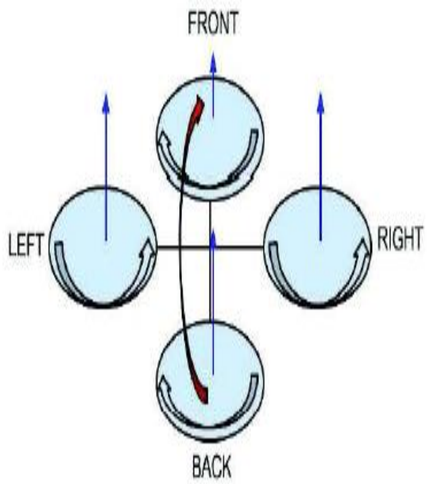

Fig. 15: Pitch movement

3. **Yaw**: Yaw is provided by increasing (or decreasing) the speed of the front and rear motors or by increasing (or decreasing) the speed of the left and right motors. This causes the quad copter to turn along its vertical axis in the direction of the stronger spinning rotors. Figure 16 shows an example of yaw movement of a quad copter. As the front and back motor slows down, the forces created by the corresponding rotors are less then the forces created by the left and right rotors. The quad copter will begin to rotate in the same direction as the faster spinning rotors due to the difference in torque forces. This movement is represented by the red arrow.

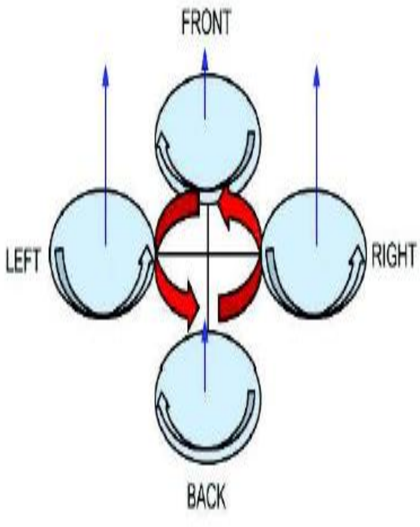

Fig. 16: Yaw movement

CHAPTER 3: SYSTEM COMPONENTS

Following are the main components used in our hexacopter. All the components are briefly discussed below:

1. Frame
2. DC brushless motor
3. Propeller
4. Spraying mechanism
5. Electronic speed controller
6. Battery
7. Landing gear
8. Radio Control
9. Flight Controller

1. Frame

The frame is the holding structure of the UAV. Function of the frame is to support and hold all other components of the UAV. The frame has six arm and two mounting plates, where one is called upper plate and another is called lower plate. The material of the frame is Aluminum (5059). The upper plate holds both batteries and ESC (Electronic Speed Controller). A mounting plate is provided below the lower plate. The mounting plate holds the spraying mechanism and landing gear. As shown in figure all six arms are mounted between upper and lower plate. Each arm holds one DC motor. The shape of the frame is hexagonal as the requirement is of six arms.

Sr. No.	**Material**	**Modulus of Elasticity (GPa)**	**Density (Kg/m3)**	**Ultimate Tensile strength (MPa)**
1	Aluminum Alloy			
	A 2219	73.8	2840	172- 476
	A 6015	76	2690	190- 270
	A 6061	70	2700	124 – 290
	A 5059	74.3	2660	330
	A 6082	71	2710	140 - 330
2	Carbon Fiber	70	1600	600
3	Balsa Wood	3	130	14
4	G10	16.5 - 18.6	180	448 - 517

(Table 1)

There are many materials available in the market which can be used to make frame. We have compared several materials. Comparison of the various material is shown in the below table 1

From above table, we have selected Aluminum Alloy of grade A 5059 due to its better mechanical properties as compared to other materials. Aluminum is also far cheaper than other materials also other materials such as carbon fiber and G10 have batter properties but they are relatively costlier than the aluminum.

2. DC brushless motor

Brushless DC electric motors (BLDCM) are also known as electronically commutated motors (ECMs) or synchronous DC motors, are synchronous motors powered by Dc electrically via an inverter or switching power supply by which AC supply is produced by which each of the phase of the motor through a closed loop controller. The controller generates pulses of current to the DC motor windings by which the speed and the torque of the motor can be controlled. Components of the BLDC is shown in the Fig. 18

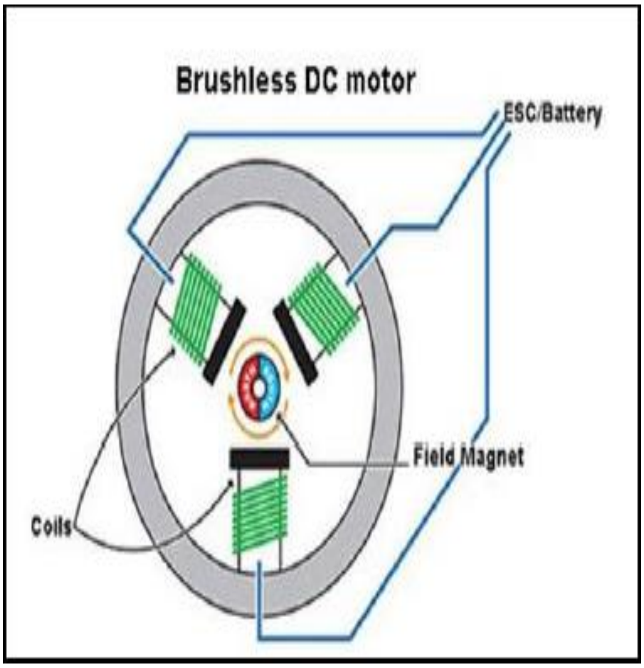

Fig. 17: Simple BLDC diagram

Compared to the brushed DC motors or an induction motor the BLDC have many advantages as mentioned below

1. Higher efficiency and reliability
2. Lower acoustic noise
3. Smaller and lighter
4. Greater dynamic response
5. Better speed versus torque characteristics
6. higher speed range
7. longerlife

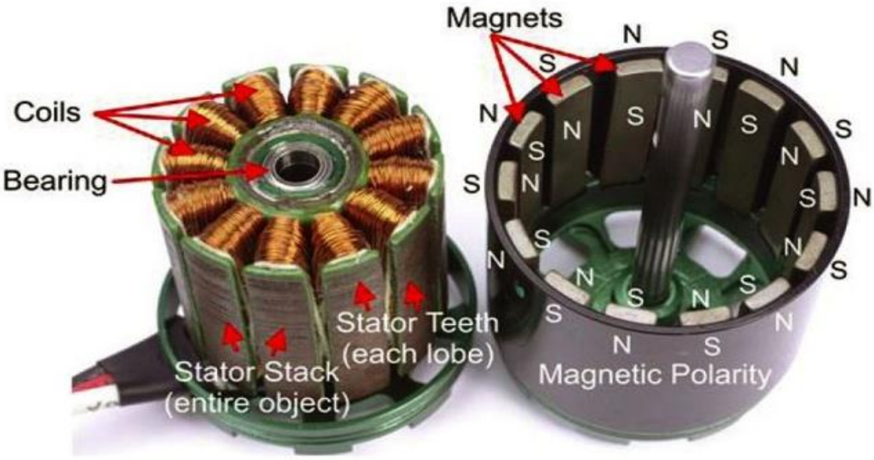

Fig. 18: Out runner components

Selection of the motor primarily depends upon the thrust required to be generated. Generally the Motors used in this type of project come with standard propeller diameter and thrust to be generated. Usually motors are designated in Kv (velocity factor- rpm/voltage). Suitable pair of the propeller and motor should be taken as Lower the Kv, bigger the propeller diameter and higher the Kv, lesser the propeller diameter.

Now as shown in the below table-2, as our drone size if big we are going to use a **10** × **4.5**, the ideal DC motor size for our drone can be selected any motor less than or equal to **1000Kv.** This pair will give sufficient torque for the the drone.

Frame Size	Prop Size	Motor Size	KV
150mm or smaller	3″ or smaller	1105 -1306 or smaller	3000KV or higher
180mm	4″	1806	2600KV – 3000KV
210mm	5″	2204-2208, 2306	2300KV-2600KV
250mm	6″	2204-2208, 2306	2000KV-2300KV
350mm	7″	2208	1600KV
450mm	8″, 9″, 10″ or larger	2212 or larger	1000KV or lower

(Table 2)

3. Propellers

A propeller is composed of a number of blades that rotate around an axis. Propellers are one type of fan that transmits power by converting rotational motion into thrust force in opposite direction. A pressure difference is produced between the forward and rear surfaces of the aerodynamic-shaped blades, and any fluid in which it is rotating (such as air or water) is accelerated behind the blade

Propellers are used to generate the thrust for the hexa copter to hover or lift. These are in different variants which are classified based on their diameter and pitch by which they travel. They are designated on the basis of their pitch and diameter. Selection of the right propeller depends upon the required thrust as well as the motor size. Each motor has its own suitable propeller size on each it gives maximum thrust and torque as well as efficiency. To create maximum thrust we use to have two "standard rotation" and two "right hand rotation" propellers.

It is also necessary to rotate the all propeller rotate in the opposite direction to each other. So ideally the reaction torque at the center will be zero. It is also very important as far as hovering purpose of the UAV

The Hovering or Static position in the air of hexa copter will be achieved by the three pairs of rotors are rotating in clockwise and remaining three will be in the counter-clockwise respectively with same speed. By three rotors rotating in clockwise and counter-clockwise position, the total sum of reaction torque is zero and this allowed hexa copter in hovering position. Counter clockwise and clock wise propellers are shown in Fig. 19.

Fig. 19: CCW and CW propellers

Material

Propellers consist of a number of materials including plastic, carbon fiber, wood etc. Unique capabilities and characteristics can be achieved from each type of materials such as carbon fiber and wooden propellers are a bit hard and provide smooth flight. Propellers made of plastic, on the other hand, are more durable and reliable.

Number of Blades

Dual blade propellers are the most commonly used propellers for the multi copter UAV. Drone racers and freestyle drones take a fancy to tri-blade propellers. Quad-blade and hex-blade-propellers are also available in the market. As a matter of fact, the more blades a propellers have the more surface area it will boast and hence will produce more thrust. However, in such a case, the propeller will draw more current from the batteries and will result in lesser overall efficiency.

Fig. 20: three blade propeller

Fig. 21: two blade propeller

Both two blade and three blade propeller are shown in Fig. 20 and Fig. 21 respectively

4. Battery

Battery is one of the very important and essential components of the UAV. It is the main power source of the all electronic components. Battery is also very important regarding to the flight time and the capacity of the UAV. As flight time is directly related to the Battery capacity.

In the market, there are many type of batteries available as per size, capacity, type. Generally higher capacity (mAh- mili Ampere hour) batteries are the commonly used and also they are the most suitable batteries foe the heavy pay load UAV.

Lithium polymer batteries (LiPo) are most popular for powering remote control aircraft due to its light weight, energy density, longer run times and ability to be recharged. We have selected two 5500 mah, 12 V, 3 cell, 20 C Li-Po batteries for our project because the payload of our project is quite large and foe achieving better flight time.

Fig. 22: Li – Po batteries

(Table 3)

Solution	Power Requirements	Cost	Size Req.	Complexity or Risk	Pump Ability	Score
Gear Pump: 1 to 1	12V Motor	Med	High	Low	Med	12
Geroter	12V Motor	Med	High	Low/Med	Med	11
Geroter with Chamber	12V Motor	Med	High	Med	Med	10
Centrifugal Pump	12V Motor	Med	Med	Low	High	16
Diaphragm Pump	12V Motor	Low/Med	Med	Low	High	17
Rotary Vane Pump	12V Motor	Med	High	Med/High	Med	9
Screw Pump	12V Motor	High	Med/High	Med	Med	9
Pneumatic Pump	Pneumatics	Med	Med/High	Med/High	Low/Med	9

5. Spraying Mechanism

Spraying mechanism consist of a pump, battery, storage tank, baffle plate, strainer and a nozzle. Spraying mechanism the main components which directly affects the design and the performance of the hexa copter. The weight of the all components of the spraying should be as low as possible. The system which will be used in our hexa copter is shown in the fig.23.

Our spraying mechanism is all in one type unit in which all components are assembled together in one unit. Approximate weight of our spraying system is 5 kg. Weight of the pesticides will be extra weight to the system.

As shown in fig. 23, pesticide is filled form the top of the Storage tank. A strainer is provided for purifying the pesticide if any contaminated particle or any substance is present there. Baffle plates are provided in the storage tank. It reduces the motion of the liquid in the tank while hexa copter is moving in forward direction. Pump, Motor and Battery are mounted at the bottom of the tank. As the pump is rotated by a DC motor sucks the pesticide and then it pressurizes the pesticide. High pressure pesticide is transferred to the all nozzles via tubing system.

Various pumps that can be used in this system are compared in the table-3. Form which the diaphragm pump is most suitable for our requirement. As we can see in the table the score of the diaphragm pump is better from all other pump. In our system, pump can generate a maximum pressure of bar

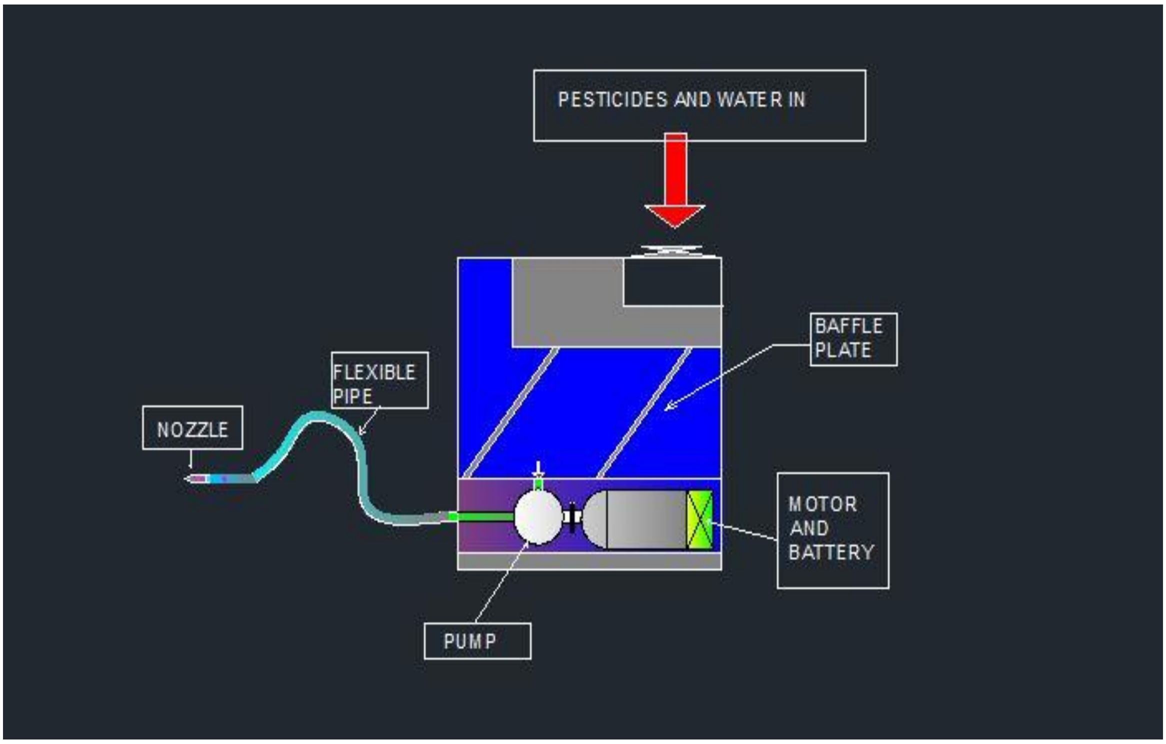

Fig. 23: Spraying Mechanism

6. Electronic Speed Controller (ESC)

An electronic speed control or ESC is an electronic circuit with the purpose to vary an servo-motor's speed, its direction and possibly also to act as a dynamic brake. ESCs are often used on motors essentially providing an electronically-generated three-phase electric power low voltage source of energy for the motor.

Fig. 24: ESC

It converts the PWM signal from the flight controller or radio receiver, and drives the brushless motor by providing the appropriate level of electrical power. BEC stands for Battery Elimination Circuit. It is the motors that draw current from the ESC's, so the ESC must be rated for the maximum Amps of the motor you are using. Ideally the ESC ampere should be double than the a maximum ampere drawn by DC brushless motor

First thing to look at when choosing ESC is the current rating, which is measured in Amps. Motors draw current when they spin, if you draw more Amps than your ESC can handle, your ESC will start to overheat and eventually fail. A catastrophic failure can even end up with your ESC in flames! Three things that tend to increase your current draw and put more stress on your ESC:

- Higher motor KV
- Larger motor size (stator width and height)
- Heavier propellers (length and pitch)

7. Landing Gear

Landing gear for a UAV helps in many ways, and although some drones land directly on their bottom plate (normally to save weight), using landing gear cane be beneficial in many ways:

- Providing clearance between the bottom of the UAV and a non-flat surface such as grass (or small rocks)
- Providing clearance between the battery pack / gimbals and the ground

Fig. 25: Landing Gear

- In the event of a hard landing, it’s ideally the landing gear which will break(And be replaced) rather than the frame
- The right landing gear can also provide flotation (lightweight pool noodles etc.)

8. Radio Control

Radio Control (RC) communication normally involves a hand-held (hobby) RC transmitter and RC receiver. For UAVs, you need a minimum four channels, and more are suggested, even if they are not used. Normally these channels are associated with:

- Pitch (which translates to forward / backward motion)
- Elevation (closer to or farther away from the ground)
- Yaw (rotating clockwise or counter-clockwise)
- Roll (to strafe left and right)

Additional channels can be used for any of the following,

- Arming / disarming the motors
- Gimbals controls (pan up/down, rotate clockwise / counter-clockwise, zoom)
- Change flight modes (acrobatic mode, stable mode etc)
- Activate / deploy a payload, parachute, buzzer or other device
- Any number of other uses

Most drone pilots prefer handheld control, meaning RC systems are still the number one choice for controlling a UAV. On its own, the receiver simply relays the values input into the controller, and as such, cannot control a UAV. The receiver must be connected to the flight controller, which needs to be programmed to receive RC signals. There are very few flight controllers on the market which do not directly accept RC input from a receiver, and most even provide power to the receiver from one of the pins.

Fig. 26: RC Transmitter

9. Flight Controller

The flight controller is the nerve center of a drone. Drone flight control systems are many and varied. From GPS enabled autopilot systems flown via two way telemetry links to basic stabilization systems using hobby grade radio control hardware, there is an open source project for you.

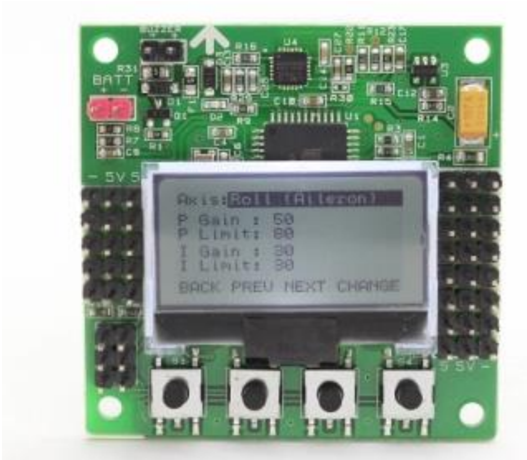

Fig. 27: Flight Controller

CHAPTER 4: DESIGN AND CALCULATION OF DRONE

For designing a Drone, there are some parameters which we need to consider while calculating. Parameters which we are considering for the design of a drone are mentioned below. All the parameters we are taking into account will directly affect the design and performance of a drone. Below parameters should be selected in such a way that they should full fill our requirement.

- Frame material
- Weight
- Thrust
- Motor capacity
- Battery size
- Selection of arm cross-section
- Flight time

1. Frame Material

Frame material is very important factor while considering the strength of the drone and the weight if the drone. Frame material should be selected in such a way that it should have low weight with high strength. It should be able to withstand the weight of the all the mountings as well as spraying mechanism.

There are many materials available in the market which can be used as drone material. As we have discussed in this report before in the table – 3, carbon fiber and Aluminum are the most suitable and widely used material for the drone. Carbon fiber is very light weight and also has excellent mechanical properties such as ultimate tensile strength, Modulus of elasticity and Density. But the cost of the carbon fiber material relatively very high it cannot be used here. So we have selected Aluminum alloy A5059 as our drone material.

2. Weight

Finding the approximate weight of the drone is the most important factor before starting to design the drone. For finding the total system weight, first of all we need to find out the weight of each component individually.

As we are making a high payload drone, weight of each component will be higher. Weight of the frame is depends upon the density of the material and volume of Upper plate, Lower plate and all six arms.

To lift heavy weight, high capacity motors and batteries are required. Approximate weight of all components id shown in below Table – 4

Sr. No.	**Component**	**Weight (kg)**
1	Upper Plate	0.8
2	Bottom Plate	0.8
3	Mounting Plate	0.8
4	Arms (6)	1.02
5	Battery(2)	0.9
6	Tank + Battery + Pump +Pesticide	6
7	DC Brushless Motor(6)	0.39
8	Nozzle + Piping system	0.2
9	Motor Mount and Nozzle pivot	0.150
	Total Weight	**11.16kg**

(Table 4)

3. Thrust

The force normal to the propellers required for providing motion to the hexa copter is termed as thrust. This force is generated with the help of rotors which spin at a certain angular velocity. Thrust force is the force which is required to lift the Drone. Ideally it should be equal to the weight and gravitational pull of the earth. But for safe lifting of Drone it should be double than the weight of the drone. The thrust force generated by each propeller can be given as below

$$\textbf{Thrust Force}, \mathbf{F_t = C_t \times \rho \times A \times V_r^2}$$

Where, C_t = Co efficient of Thrust = 0.05

4. Motor calculation

The motors should be selected in such a way that it follows following thrust to weight Relationship Ratio.

Thrust / weight = ma / mg = a / g

The selection of the capacity of the motor can be done on the basis of thrust to be generated to lift the hex copter. Motors are generally designated in Kv, which means rpm/voltage. So the motors should be selected on their rpm.

The rpm of the motors can be obtained from the equation of the thrust force and after finding rpm and on the basis of the propeller diameter we can easily choose the best suitable motor for our hex copter.

Vertical takeoff and vertical landing (VTOL) is possible only when, (a / g) > 1 or in other words, the total thrust to total weight ratio should be greater than 1 so that the hex copter can accelerate in the upward direction. In this case, we assumed that,

Total Thrust = 2 × (Total weight of Hex copter)

Let, W = Total weight of the hex copter, N

d = diameter of the propeller, m

P= pitch of the propeller, m

V_r = peripheral velocity of the propeller, m/sec

N = Revolution of the DC brushless motor, rpm

F_t = Net thrust force, N

ρ = Density of air, kg/m^3

FOS = factor of safety = 1.5

As we know that the approximate weight of the quad copter is 11.16 kg but for calculation we are considering the weight of the quad copter as 12kg.

So Total Weight, W = 12 kg = 12 × 9.81 = **118 N**

Now as we know that the net thrust required to lift the hex copter should be equal to the weight of the the hex copter, so the net thrust can be given as

Net Thrust required to lift the quad copter = **118 N**

But as we have seen before that net thrust required t hover the hex copter or for the vertical takeoff and landing of the hex copter, the net thrust which is required to lift the hex copter should be doubled in order to obtain maximum safety. Also there will be definitely certain amount efficiencies of motors, propellers and batteries. We also need to consider factor of safety.

Thrust required to hover the Hex copter = $\mathbf{2 \times 118 = 236\ N}$

For safety purpose considering FOS $\mathbf{= 1.25}$

$\therefore$ Net Thrust Force, F_t = $\mathbf{1.25 \times 236 = 295\ N}$

Now for the calculation purpose we need to have either the diameter of the propeller or the rpm of the motor. Otherwise we cannot find required size of motor. So,

Let's consider propeller size as **10 × 4.5**

Where, Diameter of propeller, **d** = 10 inch = 254 mm = **0.254 m**

Pitch, P = 4.5 inch = **0.114 m**

- ✓ Peripheral Velocity of the propeller, $\mathbf{V_r} = \frac{\mathbf{\pi d N}}{\mathbf{60}}$

$$\therefore \mathbf{V_r = \frac{\pi \times 0.254 \times \mathit{N}}{60}}$$

$$\therefore \mathbf{V_r = 0.013 \times N\ m/sec}$$

- ✓ Area of propeller, $\mathbf{A} = \frac{\pi}{4} \times \mathbf{d^2}$ $\mathbf{= 0.0506\ m^2}$
- ✓ Density of air, $\boldsymbol{\rho}$**= 1.225 kg/m³**

As we know the thrust force, we will substitute values founded from above equation in the equation of thrust and will find out rpm of the one DC motor.

- ✓ Total number of motors is 6. So thrust force of each motor, $\mathbf{F_t}$ = **295/6 = 50 N.**

Substituting each value in the equation of thrust and finding the rpm (N) required of single Motor to fly hex copter.

$$\therefore 50 = 0.05 \times 1.225 \times 0.0506 \times (0.013 \times N)^2$$

$$\therefore N^2 = 995461 \text{ rpm}$$

$\therefore$ **N = 9770 rpm**

Now we know the required RPM of the motor to fly the copter, we can easily select the motor of required capacity. Taking table – 2 as a reference, we can clearly see that for the propeller size ,more than or equal to 8,9 or 10 inch, a DC motor of 1000 kv or lesser would be most appropriate. Also frame size of our hex copter will be more than 450mm.

Also some rules also suggest that for generating more torque with large sized propeller a small kV motor will give highest efficiency. Because they will rotate at low speed and generate more torque. Generally higher rpm motors are not suited for large size propeller as they do not generate sufficient torque to lift the copter

5. Selection of cross section of the copter's Arm

Cross section of the arm may be of many shapes such as I shape, T shape, Circular shape, and Hollow rectangular shape. Shape of the arm cross section is very important when we are looking for the strength frame. Cross section of the arm should be selected in such a way that it possesses maximum strength with lowest possible weight. For that we need to find out section modulus for various cross sections and that we have to compare them.

So we have considered two cross sections for the comparison. Material for the both the section is same as Aluminum alloy A5059. We will find out section modulus for both cross sections. Than on the basis of the section modulus we will find out dimensions each cross section.

Now for finding out cross section of any cross section we need to use the equation of bending moment. The equation for the bending moment cab be given as below,

$$\frac{\boldsymbol{M}}{\boldsymbol{I}} = \frac{\boldsymbol{\sigma}}{\boldsymbol{Y}} = \frac{\boldsymbol{E}}{\boldsymbol{R}}$$

Where, M = bending moment, N·mm

Z = Section modulus, mm^3

σ = Bending stress, N/mm^2

I = Moment of Inertia, mm^4

Y = Distance from extreme fiber to neutral axis, mm

✓ Bending Moment, M = W × l = 50 × 508 = **25400 N·mm**

Where, l = length of the Arm = 2 × d = 2 × 254 = **508 mm**

We will find dimensions for both cross sections and will analyze for stresses and deflection of the arms. Two cross sections which are selected are mentioned below.

(1) I Section (2) Hollow Rectangular section

We know that materials for both cross sections are same. So the ultimate tensile strength for both cross sections will be same. Ultimate tensile strength for A5059 material is 330 N/mm^2.

Let's consider factor of safety as 5. So working stress can be given as,

∴ Bending Stress, **σ = 66 N/mm^2**

Now as we know that $\mathbf{Z} = \frac{\mathbf{I}}{\mathbf{Y}}$, so substituting the value of Z in the equation of bending moment, we get,

$$\mathbf{Z} = \frac{M}{\sigma}$$

✓ Section Modulus, $Z = \frac{M}{\sigma} = \frac{25400}{66}$ = **384.84 mm^3** (same for both cross section)

(1) I – Section

Assuming B = D and thickness of section, t = 1.2 mm

$$\therefore \mathbf{Z} = \frac{\mathbf{BD^3 - bd^3}}{6D}$$

$$\therefore 384.84 = \frac{BD^3 - bd^3}{6D}$$

∴ **B = D = 38.7 mm** (Solving the above equation by trial and error method)

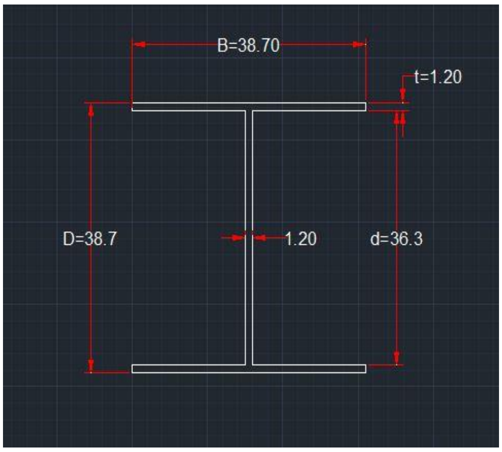

Fig. 28: I section

(2) Hollow Rectangular Cross Section

Assuming B = D and thickness of section, t = 1.2 m

$$\therefore \mathbf{Z} = \frac{\mathbf{BD^3 - bd^3}}{\mathbf{12}\boldsymbol{D}}$$

$$\therefore 384.84 = \frac{\mathrm{BD^3 - bd^3}}{12\mathrm{D}}$$

$\therefore$ **B = D = 25.4 mm** (Solving the equation by trial and error method)

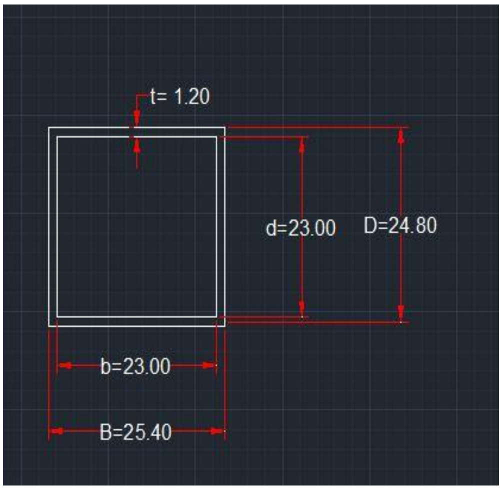

Fig. 29: Hollow rectangular Section

By doing above calculations we have concluded that the arm made of Hollow rectangular cross section has same strength as I Section having smaller dimensions and lesser weight**.** So we are going to use hollow rectangular cross section as arm. The dimensions of the hollow rectangular cross section id shown in Fig. 29

6. Flight Time

In general the flight time of the hex copter is primarily depends upon the capacity of the battery. Other than that weight and speed of the hex copter can affect the flight time of the hex copter. For having more flight time we can reduce the overall weight of the hex copter. Battery capacity can be also increased in order to obtain more flight time. But ultimately it will increase the weight of the hex copter.

Here in our hex copter we are using two number of three cell Li Polymer batteries. Capacity of each will be approximately 5500 mAh. Maximum voltage of the battery is 12V. We have six DC motors each will draw a maximum of 12 Ampere.

- ✓ Expected flight time can be given by,

$$\textbf{Flight Time} = \frac{\textbf{Capacity of Battery in "Ah"}}{\textbf{Max cuurent drawn by all motor}}$$

- ✓ Capacity of Batteries (2) = 5500 mAh × 2 = 11000/1000 = 11A

Our each motor draws max 12 Amp. Our copter is a hex copter and it has 6 numbers of motors. So max current drawn by the all motors will be (12 × 6) Amp. By putting the data we have related our battery an motors in the equation of flight time, we will have,

$$\therefore \text{ Flight time} = \frac{11}{12\times 6} = 0.153 \text{ Hour } \mathbf{= 9.16\ min} \text{ (at max throttle)}$$

CHAPTER 5: STATIC ANALYSIS OF FRAME OF THE HCX COPTER BY USING CREO 2.0

Static analysis of the frame is done in the CREO software. The assembly of the frame is made by using CREO software. Aluminum alloy A5059 is used as a frame material. Assembly of frame consists of top plate, bottom plate, arms. Nuts and bolts are used for joining the structure.

In this analysis thrust force is considered for analyzing purpose. The force is applied at the outer end of the each arm. The thrust force is acting on the whole surface of the arms in downward direction. Inner end where arms are mounted between two plates is taken fixed. The length of the each arm is 508 mm. Magnitude of thrust force acting on the whole frame is taken as 300N. On each arm the magnitude of force acting is 50N.

An assembly of the frame is shown in Fig.30. Shape of the both upper and lower plate is hexagonal. Cross section of the each arm is hollow rectangular.

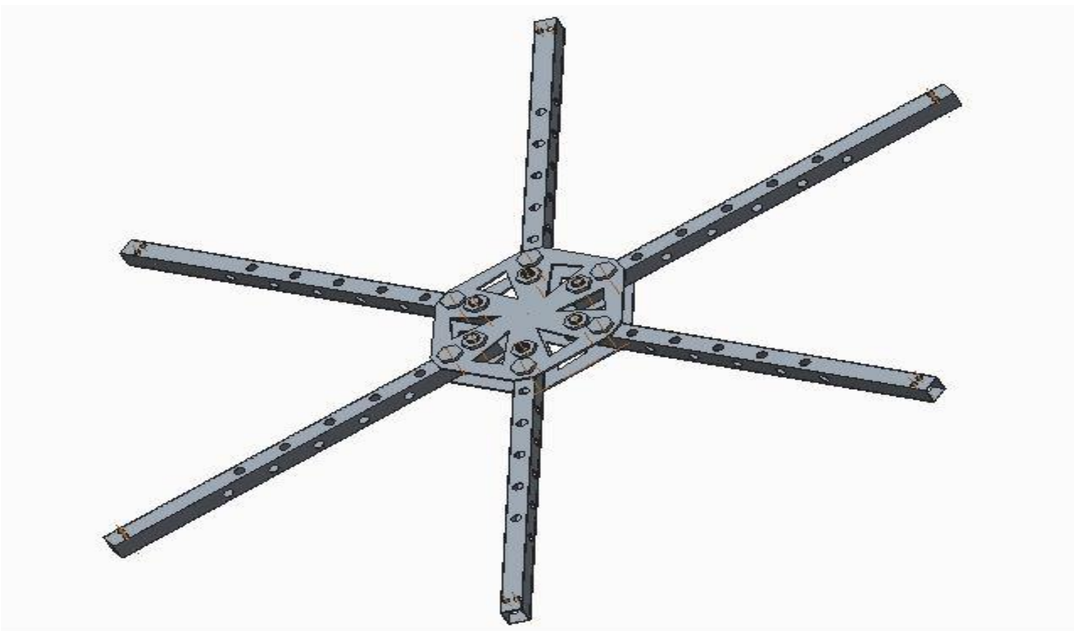

Fig. 30: Assembly of Frame

Results based on the Von – Misses stress is obtained. The results are shown in Fig.32. After performing following analysis we have concluded that the dimensions which are calculate before of the arm and of both plates are safe. From Fig.33 displacements of the arm in safe limit.

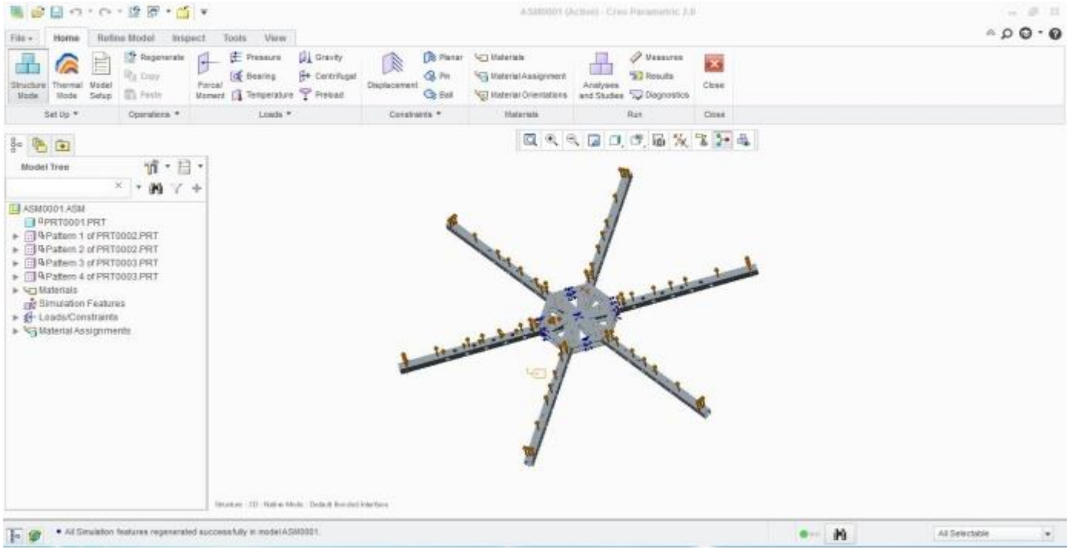

Fig. 31: Loads and constraints on Frame

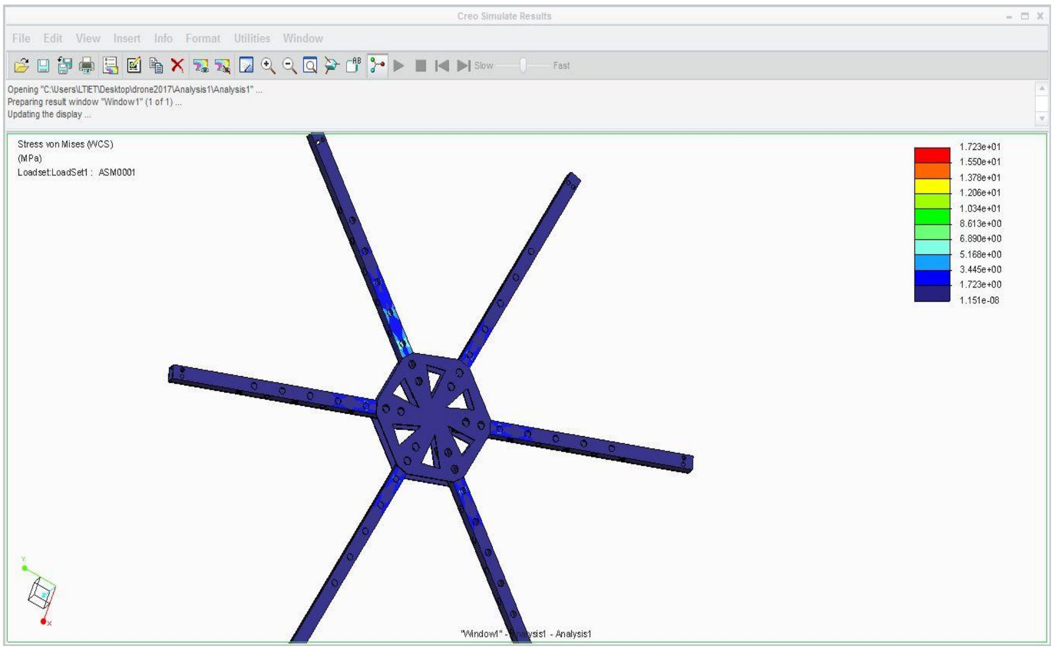

Fig. 32: Stresses and Displacement of Frame

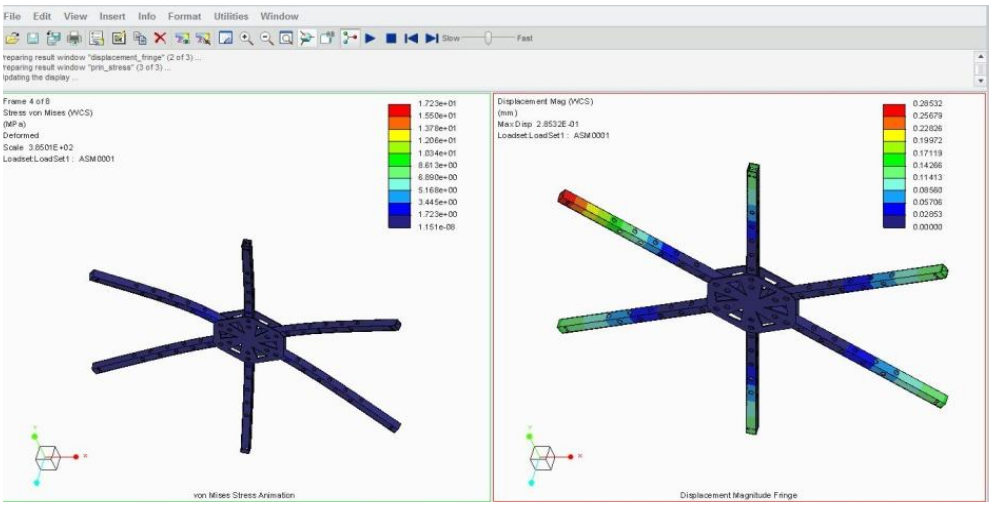

Fig. 33: Von- Misses stresses on Frame

CHAPTER 6: CANVAS SHEETS

6.1 AEIOU Summery

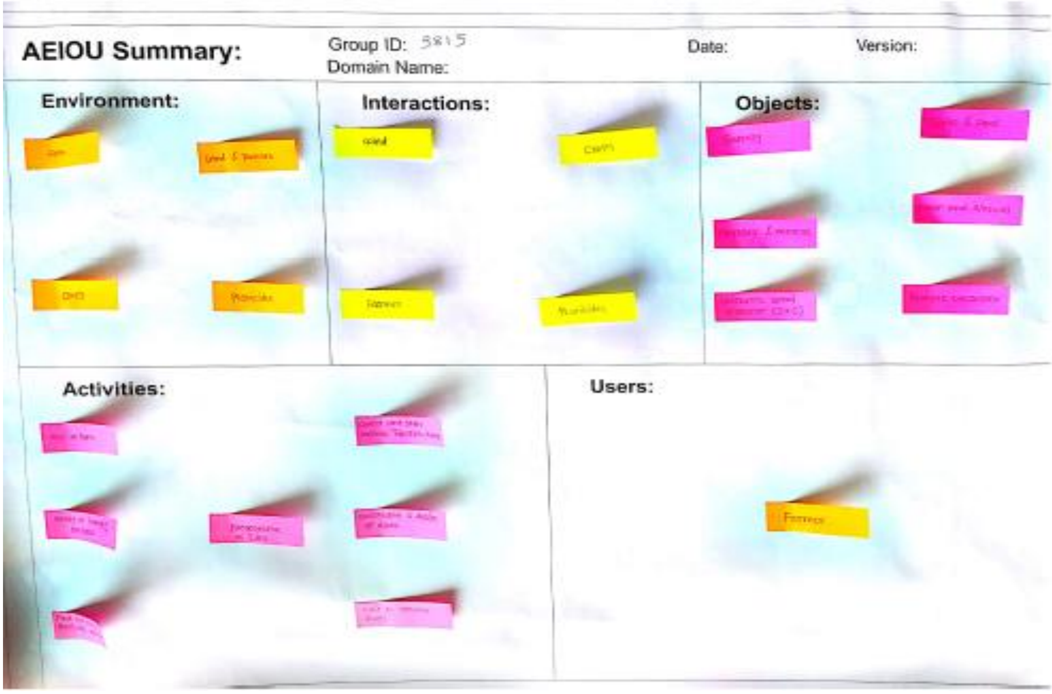

Fig. 34: AEIOU Summery

6.1.1 Environment

1. Farm
2. Crop
3. Pesticides
4. Land and frame

6.1.2 Interactions

1. Wind
2. Crop
3. Framer
4. Pesticides

6.1.3 Objects

1. Propeller and DC Motor
2. Battery
3. Pump and Nozzles
4. Electronic Speed Controller
5. Remote Controller
6. Storage tank and Piping

6.1.4 Users

1. Farmers

6.1.5 Activities

1. Visit a Farm
2. Collect and study various research papers
3. Study of various framing processes
4. Calculations and design of Drone
5. Visit to various shops
6. Find out problems in pesticides spraying
7. Presentation of possible solution

6.2 Ideation Canvas

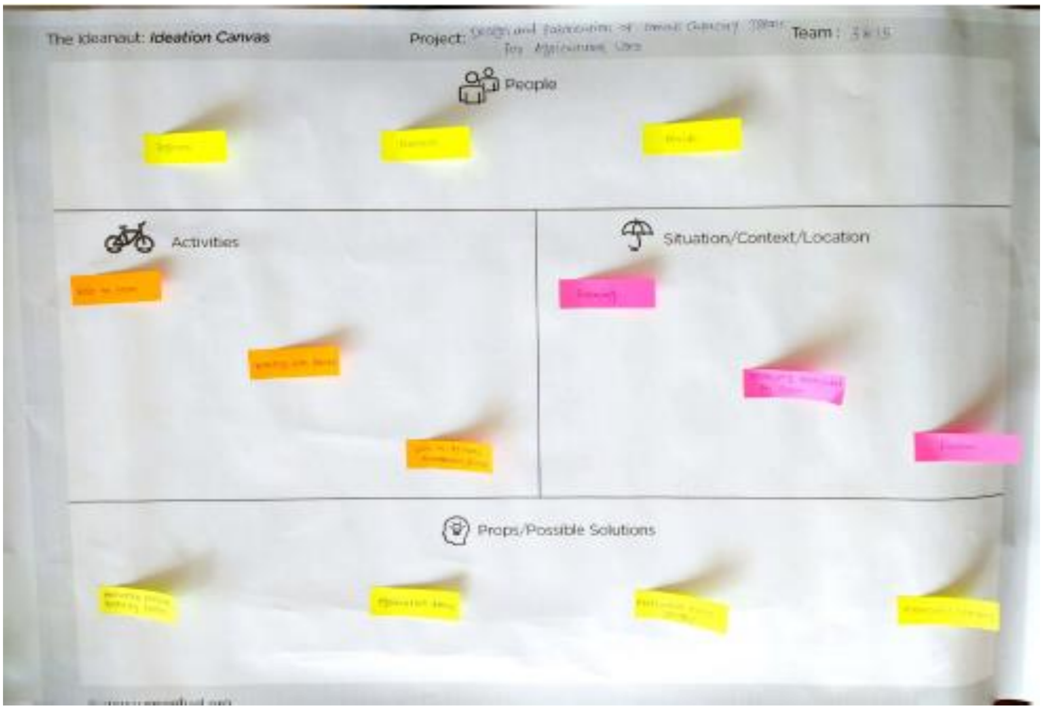

Fig. 35: Ideation Canvas

6.2.1 People

1. Engineers
2. Farmers
3. Guide
4. Students

6.2.2 Activities

1. Visit a Farm
2. Meeting and discussion with framers
3. Visit of Archna Automation, Rajkot

6.2.3 Situation/Context/Location

1. Farming
2. Spraying pesticides in farm
3. Farm

6.2.4 Props/Possible solutions

1. Aerial pesticides spraying
2. Bullet santi
3. Mechanical pump type
4. Agricultural Drone
5. Manual spraying

6.3 Product Development Canvas

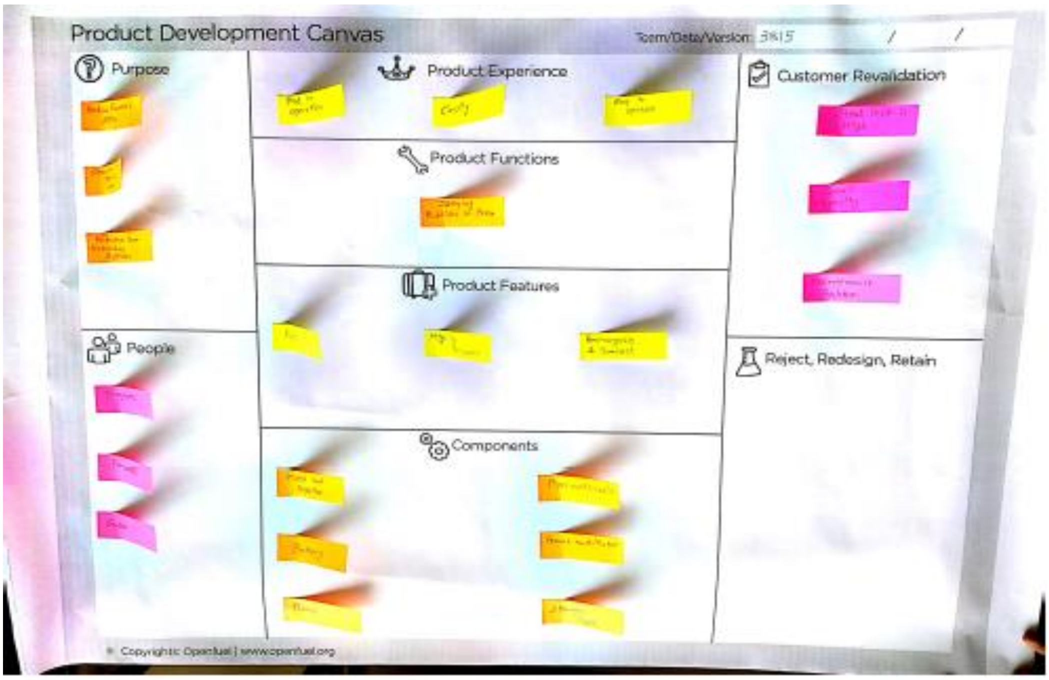

Fig. 36: Product Development Canvas

6.3.1 Purpose

1. Reduce farmer's stress
2. Reduce spraying time
3. Protection from hazardous pesticide

6.3.2 People

1. Engineers
2. Farmers
3. Students
4. Guide

6.3.3 Product Experience

1. Fast in operation
2. Costly
3. Easy to operate

6.3.4 Product Functions

1. To spray pesticides in the Farm

6.3.5 Product Features

1. Quick
2. Highly accurate
3. User friendly
4. Rechargeable and compact

6.3.6 Customer revalidation

1. Initial cost is high
2. Small capacity
3. Maintenance problem

6.3.7 Components

1. Propeller and DC Motor
2. Battery
3. Pump and Nozzles
4. Electronic Speed Controller
5. Remote Controller
6. Storage tank and Piping

6.4 Empathy Mapping Canvas

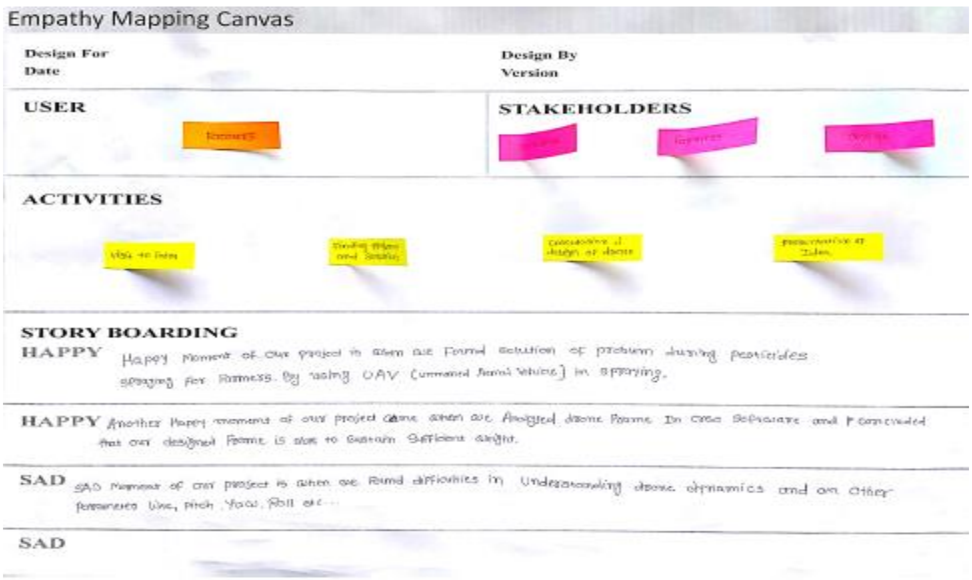

Fig. 37: Empathy Mapping Canvas

6.4.1 Users

1. Farmers

6.4.2 Stakeholders

1. Students
2. Farmers
3. Guides

6.4.3 Activities

1. Presentation of possible solution
2. Visit a Farm
3. Collect and study various research papers
4. Study of various framing processes

6.4.4 Story boarding

Happy

Happy moment of our project is when we found solution of problem during pesticide spraying for farmers by using UAV in spraying

Happy

Another happy moment of our project came when we analyzed drone frame in CREO soft6awre and concluded that our design of frame is able to sustain sufficient weight

Sad

Sad moment of our project is when w found difficulties in understanding drone dynamics and other parameters like Pitch, Roll, and Yaw

CHAPTER 7: FUTURE SCOPE

Future recommendations for the mechanical side include increasing the pesticides holding capacity and increasing the pressure output by implementing a more powerful pump. However, the current system is as optimized as possible given our weight restrictions, so a drone that is capable of carrying a higher payload would be required. By implementing a better pump, it would be able to ideally use a fluidic oscillator which would achieve similar results to the solid stream nozzle, but also be able to fluctuate the orientation of the stream mechanically.

CHAPTER 8: CONCLUSION

In this report we have given concept about an UAV which can be used in farms top spray pesticide. All the parameters such as thrust force, flight time, battery capacity, motor selection, arms cross section has to be decided before making a UAV. In this report we have calculated all the above mentioned parameter to meet our requirement. The pesticides carrying capacity of our UAV will not be very high, because we have designed it as a prototype.

The goal of the Pesticide Spraying Drone was to create a UAV system in order to aid in the containment and control of offshore vessel fires. This was completed by determining specific requirements that must be addressed in order to have a functional and effective system. In conclusion, the team was able to meet all the design requirements after researching the different choices and choosing the best options. Although the team ran into many different changes over the course of the project.

Further in the next semester we will continue to doing work on this project. The actual prototype model will be also prepared. Further testing and modification in this UAV will be done in next semester

.

CHAPTER 9: REFERANCES

[1] "Fire Containment Drone" (by William Boyd, Zachary Hood, John Lomi, Chase St. Laurent, Kyle Young)

[2] "Design And Development Of Amphibious Quad copter" mahen M.A, anirudh S Naik, chethana H.D, shashank A.C

[3] "Design of A Quad Copter and Fabrication" Anudeep M,G Diwakar, Ravi Katukam

Websites

1. quadcopterproject.wordpress.com/battery -and-f light-time/
2. www.rhydolabz.com/quadcopter-rc-c-200/brushless-motor-be22081400kv-p-1510.html
3. quadcopterproject.wordpress.com/dc-motors/
4. quadcopterproject.wordpress.com/frame-design/
5. http://euroasiapub.org/journals.php/